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THE TECHNICAL FACTORS WHICH DETERMINE THE CHOICE OF RAW MATERIAL PROCESS PRODUCT (NITROGENOUS, PHOSPHATIC OR COMPOUND FERTILISER) AND LOCATION OF PLANT

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The Technical Factors which Determine the Choice of Raw Material, Process Product (Nitrogenous, phosphatic or Compound Fertiliser), and Location of Plant.

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1. The necessity for higher and more efficient food production, particularly in the under-developed countries is self-evident. The use of chemical fertilisers is essential to obtain higher rates of production and for the efficient utilisation of the land.

2. After accepting in principle that a particular region may justify having a fertiliser plant, a number of inter-related factors must be considered in detail before a decision can be made to proceed with the project. These principal factors are -

Type of product to be manufactured

Scale of operation to be used

Raw materials to be utilised and Process Selection

Location of the plant

3. Selection of Product

(a) Before examining in detail the factors affecting the type of product or products to be manufactured, it is of interest to consider the present pattern of fertiliser production, and the changes that have occurred during the past two decades. Figure I shows the development of world fertiliser production between 1954 and 1960 on the basis of nitrogen, phosphorous (as P_2O_5) and potash (as K_2O). Table 1 shows the relative contribution of different types of nitrogenous fertilisers between 1951 and 1960. The general indication given by the figures and by the trends described in current literature is for the production of fertilisers of higher concentration of nitrogen and phosphorous and for the nitrogen consumption to have increased more than that for the phosphorous and potassium. The reason for the predominance of phosphatic fertilisers previously is probably due to the early establishment of the superphosphate manufacturing industry and to the relative simplicity and low capital cost of the plant compared with ammonia synthesis plant.

(b) The nitrogenous fertilisers which have greatly increased in production are urea and ammonium nitrate; fertilisers containing both nitrogen and phosphrus such as mon and di-ammonium phosphates

are also showing increasing popularity. Compound fertilisers based on ammonium nitrate, ammonium phosphate or urea and also containing potash have become increasingly in demand by farmers.

(c) Obviously agronomical considerations must be foremost in selecting the fertiliser to be used. Field trials must be carried out before any plant is built to ensure that the most suitable fertiliser is selected and that the farmers can be convinced of the advantages of using that material. Climatic conditions must also influence the type of fertiliser to be made and its required physical characteristics. In humid climates it would obviously be unwise to manufacture products which would absorb moisture and become difficult to handle. While it is possible to air-condition storage silos on site, it must be envisaged that materials may be stored in bulk at local distribution centres where air-conditioning is not a practicable proposition. Various techniques can be adopted to minimise the effect of climatic conditions. Products such as compound fertilisers, superphosphate, ammonium nitrate, etc., can be produced in a granular form which is more resistant to caking, and they may also be oiled and coated. The production of a spheroidal product by prilling is another technique which is used, particularly for urea and ammonium nitrate.

(d) The basic approach to the selection of a nitrogenous or phosphatic fertiliser product should be by comparing the cost per unit of nitrogen and P_2O_5 in various products and choosing the one with the minimum cost. Unfortunately, such an approach is rarely of as much value as it might appear since other factors such as the concentration of the nutrients greatly affect the cost of transport per unit of nutrient, and also its acceptability to the farmer. Such a comparison is easier when comparing straight nitrogenous or phosphatic fertilisers such as ammonium nitrate against urea, or single superphosphate against triple super phosphate. Again, however, the premium which should be allowed for the higher concentration is not easy to assess. A further advantage, for example, of higher concentration material such as di-ammonium phosphate, urea and triple superphosphate is that they may be considered as intermediate raw materials that may be locally mixed or compounded by smaller-scale manufacturers.

(e) An interesting recent development is the manufacture of slow acting fertilisers where the rate of release of nitrogen is controlled. An example of this type of material is an urea-formaldehyde fertiliser now being manufactured in France.

(f) Table 2 shows comparative production costs per ton P_2O_5 for single and triple superphosphate on the basis of the production of 45 tons/day P_2O_5. It will be seen that single superphosphate is cheaper per unit P_2O_5 to produce than triple superphosphate. However, when rail transport of the product is included, triple will be cheaper per unit nutrient than single when distances of 250 miles or more are involved.

(g) For straight nitrogenous fertilisers production costshave been compared on the basis of 250 tons of nitrogen per day for the manufacture of ammonium sulphate, ammonium nitrate and urea. For the ammonium sulphate plant, it is assumed that a sulphur burning acid plant is included. From Table 3 it will be seen that the production costs per ton N is lowest for urea, followed by that for

lime ammonium nitrate and with the cost per ton N being the highest for ammonium sulphate.

(h) It must be emphasised that these production costs are based on hypothetical circumstances and that they will in practice vary considerably depending upon individual circumstances.

4. Scale of Production

(a) It can be seen from Table 2 that raw materials costs form the largest element in the production costs of straight phosphatic fertilisers. The economics that can be achieved by larger scale operation are therefore limited and are due mainly to savings on operating labour and supervision.

(b) There is little limitation upon the maximum size of unit. Grinding mills can be obtained with unit capacities of from 15 to 30 tons/hr depending upon the characteristics of the rock. Reaction dens can be obtained with capacities ranging from 6 to 70 tons/hr superphosphate, their throughput on triple superphosphate being about half that on single superphosphate. For phosphoric acid plants it is possible to obtain filters with effective areas up to 56 square metres, equivalent to a capacity of 250/300 tons per day expressed as phosphorus pentoxide.

(c) Figure II shows the effect of the scale of production upon the total erected capital cost of ammonia plants. For the purpose of this comparison it has been assumed that the synthesis gas is derived by the partial oxidation of petroleum hydrocarbons. Apart from the obvious advantages in capital and operating costs in building very large units, the use of computers for controlling process variables becomes of economic interest for large units.

5. Raw Materials to be Utilised and Process Selection

(a) For the production of synthetic ammonia, it is obvious that the processes producing the synthesis gas mixture of nitrogen and hydrogen cannot be considered without reference to the source of the hydrogen.

(b) Prior to World War II coal and coke was the hydrogen source for about 80% of world's production of synthetic ammonia. The development of reforming and partial oxidation processes utilising petroleum hydrocarbons has reduced this figure to about 40%. Catalytic reforming processes offer the most economical route where a "light" hydrocarbon feedstock is available, ranging from methane to naphthes with boiling points up to 200°C. Plants of this type are in operation at pressures of up to 20 atmospheres. The disadvantages of this type of process are the limitations regarding the feedstock which can be used and also the sensitivity of the catalyst to impurities in the feedstock, particularly sulphur. The production of synthesis gas by the partial oxidation of petroleum hydrocarbons, as typified by the Texaco and Shell Processes has found wide acceptance. The advantage of this type of process is its ability to use feedstocks ranging from methane to heavy fuel oil. The main disadvantage is the need for an air separation plant to provide oxygen which increases the capital and operating costs compared with the reforming process. The choice between reforming and partial oxidation must largely depend upon the

relative price and long-term availability of possible petroleum feedstocks. Where cheap natural gas is available, the use of pressure reforming processes can lead to the production of ammonia at a very economical price.

(c) Phosphate rock is the raw material for phosphatic fertilisers and the principal sources are in the U.S.A., U.S.S.R., Tunisia, Morocco, Algeria and the Pacific Island of Nauru. The phosphate rock is processed into single superphosphate by the action of sulphuric acid, into triple superphosphate by the action of phosphoric acid, or the reaction of phosphoric acid with ammonia to form ammonium phosphates. Phosphoric acid for fertiliser use is normally produced by the "wet process" involving the action of sulphuric acid on the rock and the subsequent removal of the calcium sulphate by filtration. An alternative route to phosphoric acid is by reacting phosphate rock and coke in an electric furnace to produce elemental phosphorus which is subsequently converted to phosphoric acid. The "wet process" normally offers the most economical route to fertiliser grade acid. The production cost of phosphatic fertilisers is chiefly dependent upon the cost of rock and of sulphuric acid. For example, in the production of phosphoric acid, approximately 40% of the cost is accountable to phosphate rock and only slightly less to sulphuric acid. For European producers more than half the cost of phosphate rock is due to transport charges.

(d) The advantage of locating plant at the rock deposits or at least close to harbours is obvious. Future development may also be in the field of transporting more concentrated forms of phosphorus which can be utilised by fertiliser manufacturers than phosphate rock. Potassium Metaphosphate, comprising 60% P_2O_5 and 40% K_2O is an example of the type of concentrated material which might well be used as an intermediate in the production of complete fertilisers.

6. Location of Plant

(a) Obviously the first consideration in locating a fertiliser plant is the easy access to raw materials and adequate transport facilities for distributing the product from the works. These facilities must be adequate even at the peak periods during the fertiliser season. The economic advantages to be gained by locating the works at the source of raw materials has been illustrated by the phosphatic fertiliser installations under construction in Morocco and the project for the production of ammonia from cheap natural gas in Trinidad. This ammonia will be shipped in refrigerated tankers to consumers throughout the world. If the sea transport of liquid ammonia is proved to be feasible then there will be strong economic incentives to manufacture ammonia from the plentiful natural gas available in North Africa and the Middle East.

(b) The availability of water for process processes and for cooling water make-up is an obvious necessity as is also an electrical supply. Interruption to the electrical supply will gravely handicap the operation of the works and if this circumstance can arise, due say to the effect of lightning on overhead lines, it is desirable to provide a second incoming supply. While sea water can supply much of the cooling water requirements for plants located on a coast it

is still necessary for fresh water cooling circuits to be used in those items of equipment, such as compressors, where the water flow could be impeded by rust or other deposits. The use of sea water for cooling compared with fresh water increases equipment costs due to the need for special materials of construction in place of mild steel.

(c) The disposal of effluents may also be an important factor in considering site location. Gypsum (calcium sulphate) is a by-product of the manufacture of phosphoric acid by the "wet process" and presents a disposal problem. The normal way of disposing of the gypsum is to pump it as a slurry into the sea or a river. It may be found possible to utilise the gypsum for the manufacture of plaster board or for the production of ammonium sulphate, although this latter use will depend upon the relative economics of sulphuric acid manufacture. The gaseous effluents produced in fertiliser plants do not normally present difficult problems and established methods exist for dealing with them.

7. Conclusion

It will be appreciated that the various problems related to the establishment of a fertiliser factory have necessarily been dealt with in broad outline only. Nevertheless, it is hoped that enough has been said to demonstrate that a very careful survey of the whole field is necessary before even an outline scheme can be prepared. It is hoped that, brief though it is, this paper will serve to stimulate discussion of the very large and important topics covered by its title, and so facilitate the approach to the concrete problems of increasing fertiliser production.

TABLE 1

RELATIVE CONTRIBUTIONS OF DIFFERENT KINDS OF NITROGENOUS FERTILISERS TO WORLD OUTPUT

Kind of Fertiliser	1954/55	1955/56	1956/57	1957/58	1958/59	1959/60
			Per cent			
Ammonium Sulphate	31	32	30	29	28	26
Ammonium Nitrates	27	27	27	27	25	26
Sodium Nitrate	5	4	4	4	4	3
Calcium Nitrate	6	5	5	5	5	5
Calcium Cynamide	6	4	4	4	3	3
Other forms						
"Solids"	7	10	12	13	15	16
"Solutions"	17	17	17	17	19	20
Organic Materials	1	1	1	1	1	1

(1) Fertilisers - An Annual Review of World Production, Consumption & Trade - F.A.O.

TABLE 2

COMPARATIVE PRODUCTION COSTS FOR SINGLE AND TRIPLE SUPERPHOSPHATE

Basis : 45 tons/day P_2O_5

	Single Superphosphate (18/22% P_2O_5)		Triple Superphosphate (45/45% P_2O_5)	
Total installed cost	£465,000		£700,000	
	£ Cost per ton	£ Cost per ton P_2O_5	£ Cost per ton	£ Cost per ton P_2O_5
Raw Materials	6.35	31.75	13.40	29.8
Utilities	1.10	5.50	8.70	19.4
Depreciation	0.54	2.70	1.86	4.1
Labour and Supervision	0.44	2.20	1.20	2.7
Maintenance	0.16	0.80	0.53	1.2
Overheads	0.89	4.45	2.40	5.3
	9.48	47.40	28.09	62.5

NOTES

(1) No allowance for interest has been made.

(2) A depreciation period of 10 years has been allowed for process plant and 20 years for buildings, stores, etc.

(3) Overheads have been assumed as 200% on labour and supervision.

(4) It has been assumed that all the product is bagged.

TABLE 3

COMPARATIVE PRODUCTION COSTS FOR VARIOUS NITROGENOUS FERTILISERS Basis 250 tons/day N.

	Ammonium Sulphate		Lime Ammonium Nitrate		Area	
Total installed cost	£5,350,000		£7,150,000		£6,600,000	
	£ Cost per ton	£ Cost per ton N	£ Cost per ton	£ Cost per ton N	£ Cost per ton	£ Cost per ton N
Raw Materials	4.7	22.6	2.50	12.2	3.85	8.3
Utilities	1.3	6.1	1.47	7.2	3.24	7.0
Depreciation	1.2	5.6	1.60	7.8	3.26	7.1
Labour and Supervision	0.17	0.8	0.19	0.9	0.42	0.9
Maintenance	0.34	1.6	0.44	2.2	0.93	2.0
Overheads	0.34	1.6	0.38	1.9	0.83	1.7
	8.05	38.3	6.58	32.2	12.53	27.0

NOTES

(1) No allowance for interest has been made.

(2) A depreciation period of 10 years has been assumed for process plant and 20 years for buildings, roads, off-site installations etc.

(3) Overheads have been assumed as 200% on labour and supervision.

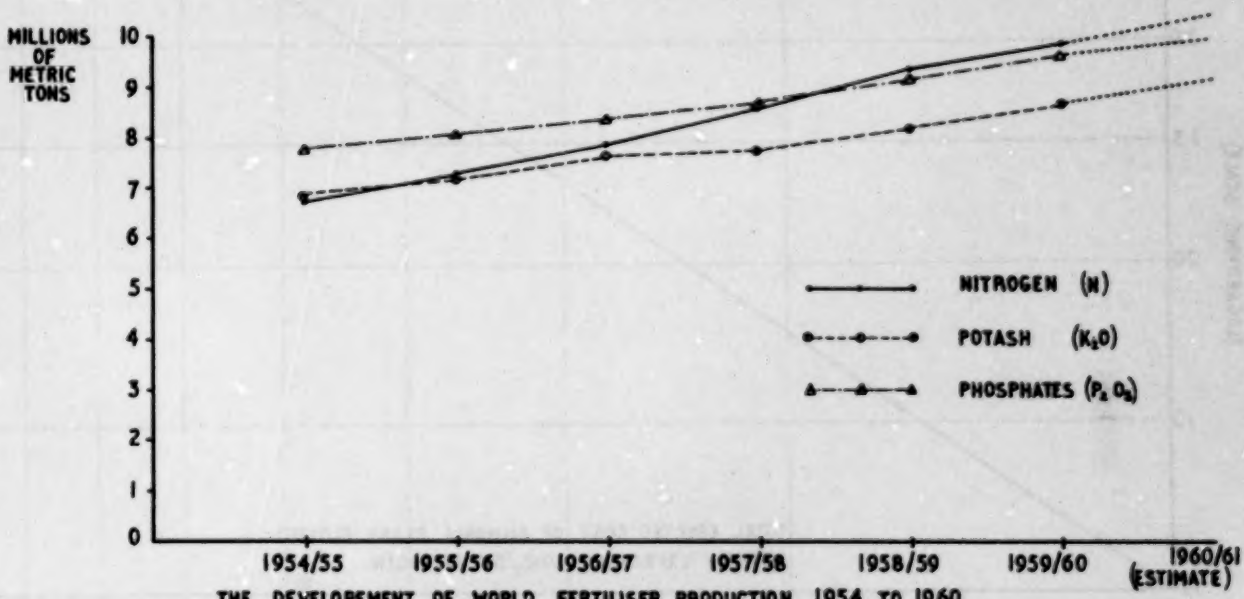
(4) For lime ammonium nitrate plant it has been assumed that a product containing 20.5% N is being manufactured.

(5) It has been assumed that half of the output for each product is being bagged and the remainder being despatched in bulk.

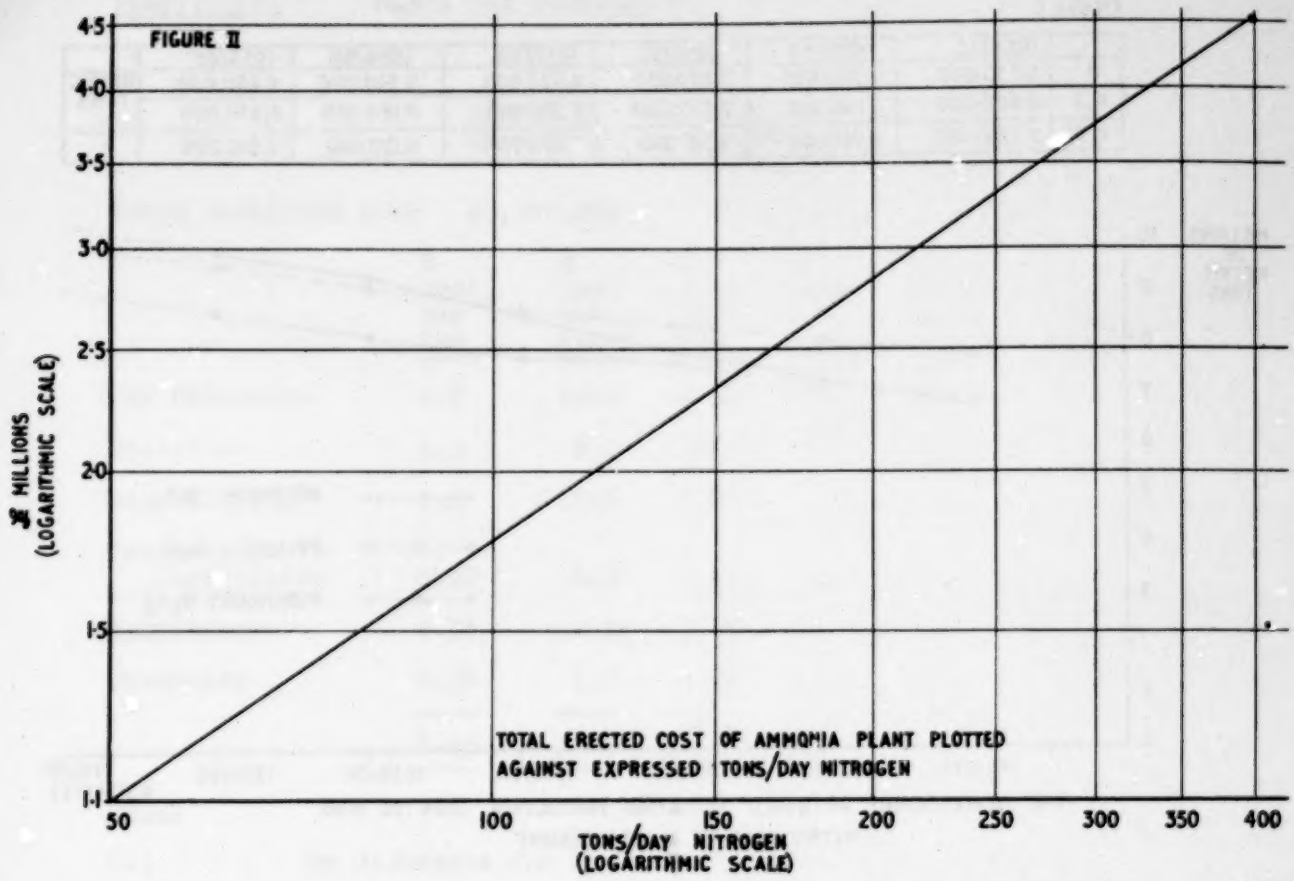
(6) The partial oxidation under pressure of heavy fuel oil has been assumed as the means of production of synthesis gas.

FIGURE I

	1954/55	1956/56	1956/57	1957/58	1958/59	1959/60	
N.	6,730,000	7,200,000	7,850,000	8,570,000	9,390,000	9,920,000	METRIC TONS
K_2O	6,800,000	7,140,000	7,610,000	7,710,000	8,160,000	8,630,000	"
P_2O_5	7,720,000	8,030,000	8,310,000	8,630,000	9,130,000	9,650,000	"



THE DEVELOPEMENT OF WORLD FERTILISER PRODUCTION 1954 TO 1960
METRIC TONS OF PLANT NUTRIENT



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